Space Weather Technical Forecast

Issued on Sunday, 25 December 2022 at 13:35 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Potential Earth-directed CMEs on 26 and 27 December with possible G1/Minor Storms and low risk of G2.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Low over the last 24 hours with only C-class flares observed. The largest region is AR3169 (Fsi/Beta), which has spread slightly over the last 24 hours. AR3171 (Cao/Beta) neighbours AR3169 and despite being simple, this region has reversed polarity to the expected order of magnetic orientation of northern hemisphere regions. The remaining regions are magnetically simple.

Multiple CMEs have been analysed over the last 24hrs, generally slow and with no significant Earth directed component however we await model data for a faster CME associated with a larger C-class flare from AR3169 approximately 25/0700 UTC.

Solar Wind / Geomagnetic Activity: Solar wind speeds have been Elevated to Strong between 550-650km/s for much of the period. Peaks of around 700-710km/s record overnight although data quality has been somewhat reduced due to Below Average density levels. A recent drop drop in wind speeds to slightly elevated to Elevated levels 450-550km/s likely due to the waning influence of the high speed stream from coronal hole 56. Total magnetic field strength was at moderate to weak levels through the 24 hours, averaging around 7nT. The north-south component, Bz, also varied weakly with no significant polarity bias. Phi angle has been predominantly positive (away from the Sun). Geomagnetic activity was Quiet to Active through the period.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) as measured at GOES16 remained at Background levels.
High energy electron flux (greater than 2 MeV), as observed by GOES16, started at background levels to rose to reach high (1e3 pfu) levels by 24/1405UTC and has oscillated between high and moderate levels close to the high threshold since that time. Electron fluence has been on an increasing trend. 4.18e7 integrated pfu recorded at 24/2359UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is expected to be mainly at Low levels, with a chance of M-class flaring.

Solar Wind / Geomagnetic Activity: A CME which left the Sun on 21 December is likely to have passed the Earth with no effects and has been removed from the forecast. Two further CMEs are forecast to potentially have Earth-impacting components. The first, which left the northeast quadrant of the approximately Sun 24/0230UTC may glance the Earth on 26 December, and another CME which left the Sun approximately 24/0800UTC may arrive at earth on 27 December based on recent Enlil forecasts.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

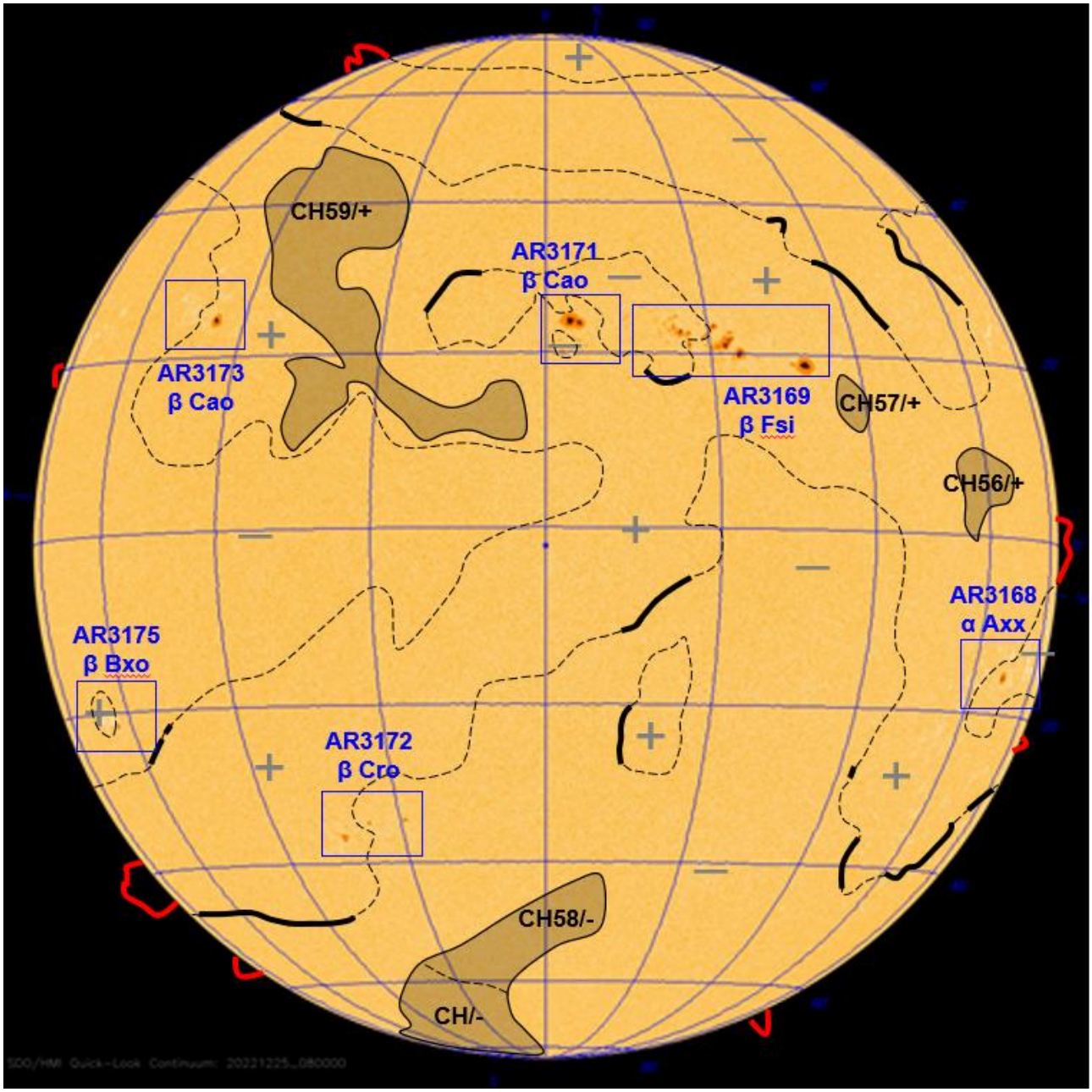
The coronal hole high speed stream from coronal hole 56 is expected to continue to wane through 25 December. A further small high speed stream may maintain higher speeds into the 26 or 27 December, but with low confidence, as the feature continues to weaken. Any further coronal hole connections may however be masked by possible CME arrivals. potential affects from the leading edge of coronal hole 59 are possible by the end of the period (28 December). Geomagnetic activity is forecast to be mainly Quiet to Unsettled on 25 December. There is then a risk of Active or G1/Minor Storm intervals on 26 and 27 December due to possible CME arrivals and a chance of these combining with residual high speed stream connections. Any CME arrival on 27 December could see residual storming persisting into 28 December.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at Background levels throughout.
High energy electron flux (greater than 2MeV) may continue at moderate to high levels through the next four days due to recent high speed stream inputs. CME arrivals could have the effect of distorting belts and potential redistributing electrons away from GEO orbits however. Confidence is therefore low for the possible behaviour of electron flux over the next four days.
Electron fluence values are likely to initially follow a slightly rising trend through 25 December likely reaching the Active threshold by the 26th December, with the subsequent trend seeing lower confidence and dependent on potential CME arrivals.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

Figure 1. Solar Analysis Valid 25/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

Geomagnetic Storms:

The next CME with a potential Earth-directed component left the northeast quadrant of the Sun early on 24 December and may glance the Earth during 26 December. Main uncertainties with this CME are the size of angular size of the cone and possible speeds, with a large margin of error across the Enlil ensemble. Given the location of the eruption, in the northeast, slight changes in initial parameters could have a significant impact on whether the feature affects Earth. A further CME which left the Sun from the southwest quadrant later into the morning of the 24 December may arrive at Earth on 27 December, although this is also low confidence due to limited imagery. Futher eruptions occurred from the vicinity of AR3168 during 24 December and during the morning of the 25 and these will be analysed once sufficient imagery becomes available.

The coronal hole high speed stream from coronal hole 56 is expected to continue to wane through 25 December. A further small high speed stream may maintain higher speeds into the 26 or 27 December, but with low confidence, as the feature continues to weaken during the last 24hrs and is no longer marked on SWPC synoptic maps. Any further coronal hole connections may also be masked by possible CME arrivals. Potential affects from the leading edge of coronal hole 59 are possible by the end of the period (28 December).

Geomagnetic activity is forecast to be mainly Quiet to Unsettled on 25 December. There is then a risk of Active or G1/Minor Storm intervals on 26 and 27 December due to possible CME arrivals and a chance of these combining with residual high speed stream connections, with a very slight chance of G2/Moderate Storm given the potential for a more direct arrival. Any CME arrival on 27 December could see residual storming persisting into 28 December.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	5	40	50	20
Strong	G3	No	1	5	5	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

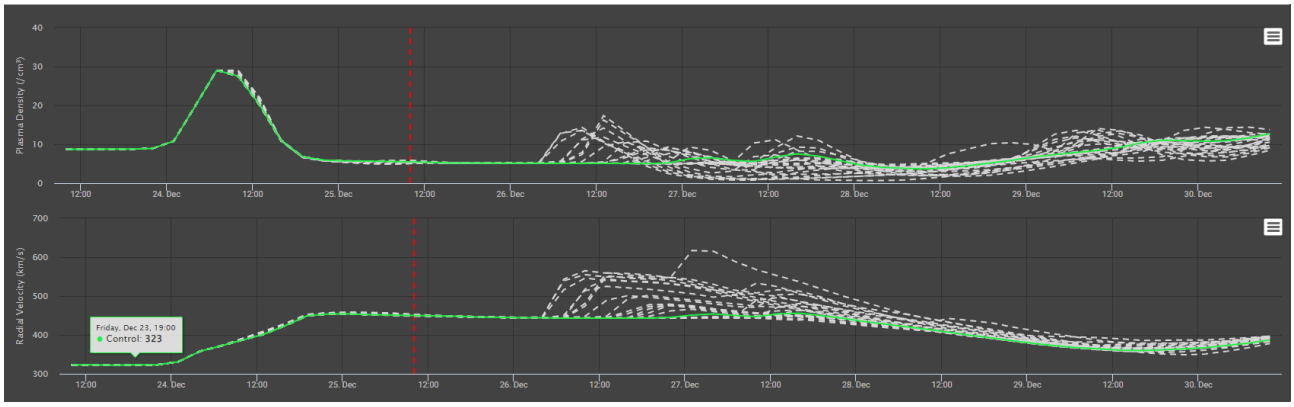
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
24/0545UTC	Partial	Filament	NE quadrant	1100km/s	26/1600UTC	Low confidence
24/1415UTC	Partial	Potentailly AR3169	NE quadrant	620km/s	27th	Low confidence

Figure 2: Latest ENLIL Ensemble output.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

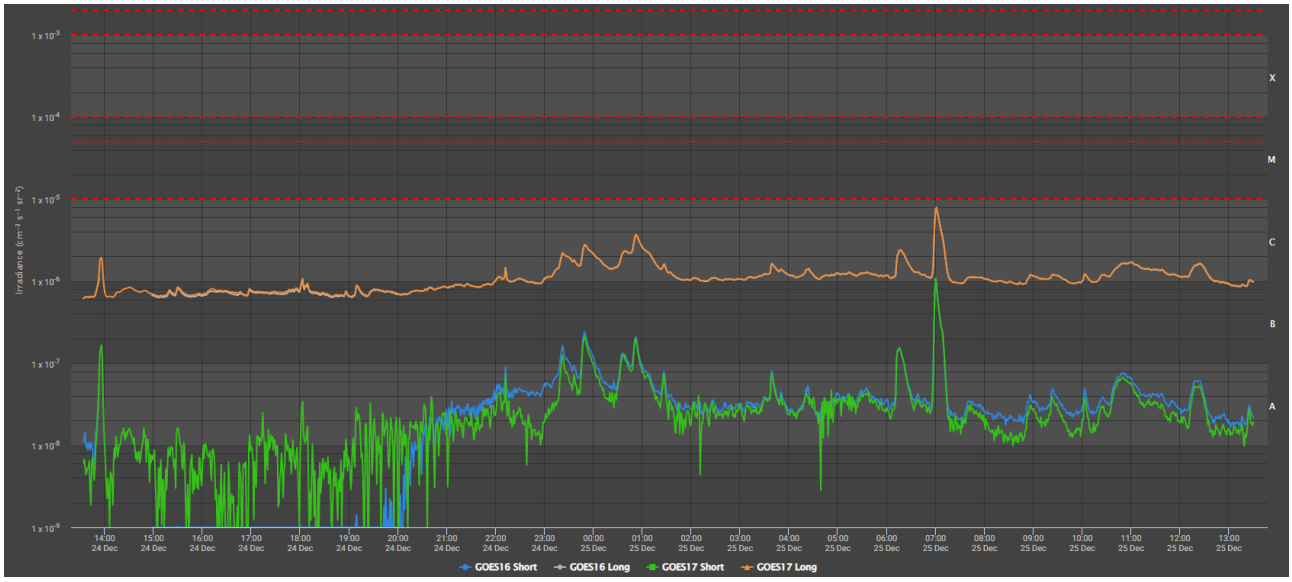
Radio Blackouts - X-Ray Flares:

Solar activity has been Low, mostly associated with the large and complex AR3169 in the northwest quadrant through the last 24 hours. There have been a series of CMEs emanating from this region and signs of possible small delta spot formation, which may be a precursor for further development.

Activity has been generally below that expected of similarly complex regions, but a 25% risk of M-class flaring is maintained based on potential for further activity. Other active regions on the visible disk remain generally stable for now. Further regions are forecast to rotate onto the visible disc later in the period, based on analysis of far sided STEREO imagery and these will be analysed once any regions become visible.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	25	25	25	25
Very Active	R3 to R5 X Class	No	1	1	1	1

Figure 3: X-Ray trace for the last 24hr



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

Solar Radiation Storms - (High Energy Protons):
The high energy proton flux (greater than 10 MeV) is expected to remain at Background levels. Forecast probabilities have been raised a little relative to recent guidance, due to the westward advance of developing AR3169, although there is as yet no enhancement above background observed at GOES16 due to flare activity from this or any other region.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.

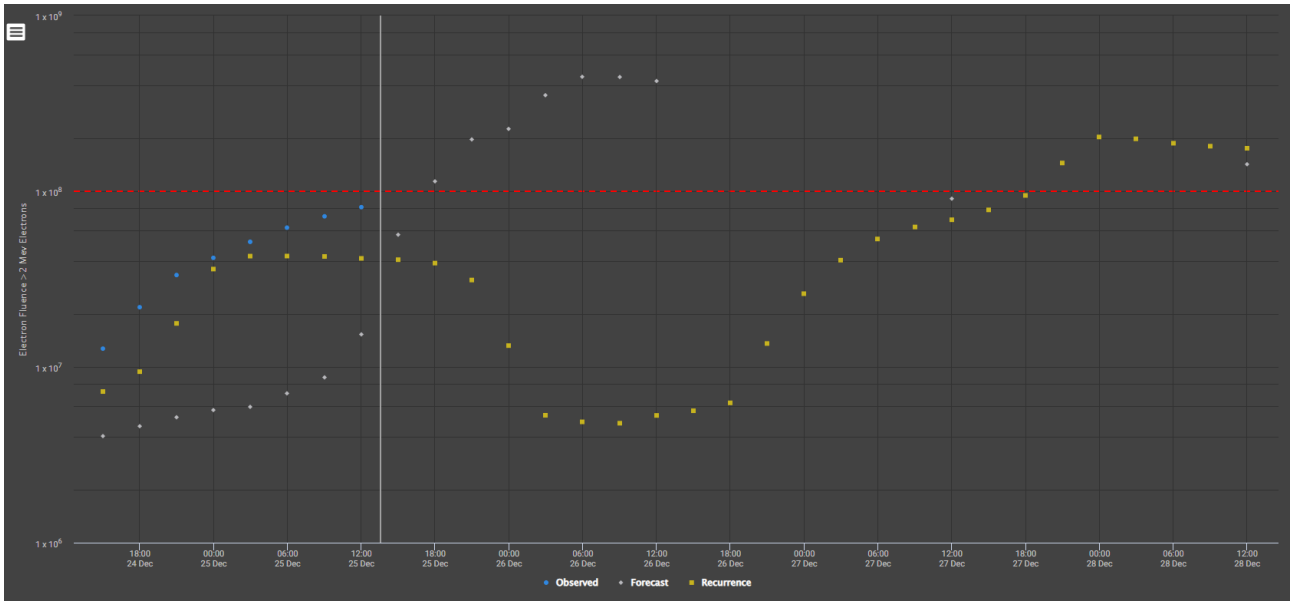
High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) is currently varying between moderate and high (1e3pfu) levels. This has coincided with a gradual weakening of the solar wind speeds and likely be a result of the radiation belts relaxing into their natural orbits following easing HSS influence. Based purely on effects from coronal holes, a slightly rising trend would be expected through the remainder of the period.

The forecast is subject to notable uncertainty however, and further rise could be limited based on the strength of any potential geomagnetic activity which could redistribute electron populations. Possible CME effects on 26 and 27 December may have the effect of compressing belts and redistributing electrons.

Electron fluence values are likely to initially follow a slightly rising trend through 25 December likely reaching the Active threshold by the 26th December, with the subsequent trend seeing lower confidence and dependent on potential CME arrivals.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	50	70	50	30
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 4: Latest REFM model output. Forecast viewed as generally good guidance.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2022. All Rights Reserved.